Test Report

Product name: AB Catalyst

Report to: AB Catalyst Company

Test category: Entrusted test

School of Energy and Environment, Inner Mongolia University of Science and Technology

School of Energy and Environment, Inner Mongolia University of Science and Technology Test Report

Sample ID	See report	**Report to**	AB Catalyst Company
Sample name	Catalyst	**Test category**	Entrusted test
Number of samples	3	**Data of sample**	April 30th, 2019
Sample status	Powdery	**Sample sender**	Murray Mortson
Test items	Catalytic combustion efficiency	**Test method**	Differential thermal DSC
Test result	See analysis report Date of issue: June 10th, 2019		
Description of uncertainty	The uncertainty expressed in terms of repeatability meets the requirements of the above standards		
Note	The combustion efficiency test of this report is not a national standard method, and the results are for reference only		

Main operator: Jian Wang Checked by: Zhijun Gong

School of Energy and Environment, Inner Mongolia University of Science and Technology Test Report (The report is only responsible for the received sample)

Report to: AB Catalyst Company
Report date: June 10th, 2019

Test conditions: The coal type is the received type for the test, the coal sample is covered with a layer of asbestos gauze, and the catalyst is placed on the asbestos gauze to ensure that the catalyst and the coal are not mixed, and the catalyst acts on the flue gas of coal combustion)

1. Coal sample amount: 100mg
2. Temperature increase rate and final temperature: 20℃/min,1000℃
3. Atmosphere: 50ml/min, Air

Test method: Differential heat test

Addition amount of catalyst by weight to the coal sample	**0%**	**0.5%**	**1.0%**	**1.5%**	**Average value**
Heating value (J/g) generated by burning sample	19,420	20,098	20,270	19,885	20,084
Adding value (J/g) created by the addition of catalyst		678	850	465	664
Additional percentage (%) of heat generated by the addition of catalyst		3.49	4.37	2.39	3.42

Main operator: Jian Wang Checked by: Zhijun Gong

Test Report

Product name： AB Catalyst

Report to： AB Catalyst Company

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School of Energy and Environment, Inner
Mongolia University of Science and Technology

School of Energy and Environment, Inner Mongolia University of Science and Technology Test Report

Sample ID	See report	**Report to**	AB Catalyst Company
Sample name	Catalyst	**Test category**	Entrusted test
Number of samples	9	**Data of sample**	April 30th, 2019
Sample status	Powdery	**Sample sender**	Murray Mortson
Test items	Catalytic combustion activity	**Test method**	Fixed-bed reactor
Test result	See analysis report Date of issue: June 10th, 2019		
Description of uncertainty	The uncertainty expressed in terms of repeatability meets the requirements of the above standards		
Note			

Main operator: Jian Wang Checked by: Zhijun Gong

School of Energy and Environment, Inner Mongolia University of Science and Technology Test Report (The report is only responsible for the received sample)

Report to: AB Catalyst Company
Report date: June 10th, 2019

Test conditions: Introduce simulated flue gas to the fixed-bed reactor, and the catalyst is placed on the asbestos gauze to ensure full contact between the catalyst and simulated flue gas, and the catalyst acts on simulated flue gas

1. Catalyst amount: 100mg
2. simulated flue gas: CO (1%) , N_2, O_2
3. Flue gas volume: 500ml/min

		CO conversion rate percentage	CO conversion rate percentage
$CO:O_2$=1:1	**Catalyst**	AB Catalyst	Blank (No Catalyst)
	500℃	57.63	2.19
	600℃	60.33	3.33
	700℃	71.03	3.83
$CO:O_2$=1:2	**Catalyst**	AB Catalyst	Blank (No Catalyst)
	500℃	53.55	2.19
	600℃	67.37	3.95
	700℃	64.10	4.12
$CO:O_2$=2:1	**Catalyst**	AB Catalyst	Blank (No Catalyst)
	500℃	63.63	2.2
	600℃	63.94	3.53
	700℃	64.21	3.95

Main operator: Jian Wang Checked by: Zhijun Gong

Test Report

Product name: AB Catalyst

Report to: AB Catalyst Company

Test category: Entrusted test

School of Energy and Environment, Inner Mongolia University of Science and Technology

School of Energy and Environment, Inner Mongolia University of Science and Technology Test Report

Sample ID	See report	**Report to**	AB Catalyst Company
Sample name	Catalyst	**Test category**	Entrusted test
Number of samples	18	**Data of sample**	April 30th, 2019
Sample status	Powdery	**Sample sender**	Murray Mortson
Test items	Catalytic combustion activity	**Test method**	Fixed-bed reactor
Test result	See analysis report Date of issue: June 10th, 2019		
Description of uncertainty	The uncertainty expressed in terms of repeatability meets the requirements of the above standards		
Note			

Main operator: Jian Wang Checked by: Zhijun Gong

School of Energy and Environment, Inner Mongolia University of Science and Technology Test Report (The report is only responsible for the received sample)

Report to: AB Catalyst Company
Report date: June 10th, 2019

Test conditions: Add 1g of pulverized coal to the fixed-bed reactor, and introduce air (change O_2 amount). The catalyst is placed on the asbestos gauze to ensure full contact between the catalyst and the real flue gas, and the catalyst acts on the real flue gas

500℃					
10% O_2			20% O_2		
Blank group	Stable for 15 minutes	Burn out in 40 minutes	**Blank group**	Stable for 10 minutes	Burn out in 33 minutes
Additive group (1g of coal)	Stable for 8-10 minutes	Burn out in 35 minutes	**Additive group (1g of coal)**	Stable for 6-10 minutes	Burn out in 28 minutes
Stable period	**Catalyst addition amount**	**CO content in flue gas (PPM)**	**Stable period**	**Catalyst addition amount**	**CO content in flue gas (PPM)**
CO (ppm) (stable for 2 minutes)	0g	55000	**CO (ppm) (stable for 2 minutes)**	0g	64000
	0.2g	53000 (3.63% reduction)		0.2g	60000 (4.68% reduction)
	0.4g	45000 (18.18% reduction)		0.4g	35000 (45.31% reduction)
	0.6g	21000 (61.81% reduction)		0.6g	44000 (31.25% reduction)

600℃					
10% O2			20% O2		
Blank group	Stable for 6 minutes	Burn out in 30 minutes	**Blank group**	Stable for 5 minutes	Burn out in 25 minutes
Additive group (1g of coal)	Stable for 4-6 minutes	Burn out in 28-30 minutes	**Additive group (1g of coal)**	Stable for 4 minutes	Burn out in 23-25 minutes
Stable period	**Catalyst addition amount**	**CO content in flue gas (ppm)**	**Stable period**	**Catalyst addition amount**	**CO content in flue gas (ppm)**
CO (ppm) (stable for 2 minutes)	0g	57000	**CO (ppm) (stable for 2 minutes)**	0g	42000
	0.2g	45000 (21.05% reduction)		0.2g	35000 (16.67 % reduction)
	0.4g	46000 (19.30% reduction)		0.4g	38500 (8.33% reduction)
	0.6g	29000 (49.12% reduction)		0.6g	31500 (25.0% reduction)

700℃					
10% O_2			20% O_2		
Blank group	Stable for 5 minutes	Burn out in 26 minutes	**Blank group**	Stable for 6 minutes	Burn out in 24 minutes
Additive group (1g of coal)	Stable for 3-5 minutes	Burn out in 24-26 minutes	**Additive group (1g of coal)**	3-4分钟稳定 Stable for 3-4 minutes	Burn out in 22-24 minutes
Stable period	**Catalyst addition amount**	**CO content in flue gas (ppm)**	**Stable period**	**Catalyst addition amount**	**CO content in flue gas (ppm)**
CO (ppm) (stable for 2 minutes)	0g	31000	**CO (ppm) (stable for 2 minutes)**	0g	24000
	0.2g	22000 (29.03% reduction)		0.2g	18000 (25.0% reduction)
	0.4g	20000 (35.48% reduction)		0.4g	20000 (16.67% reduction
	0.6g	20000 (35.48% reduction)		0.6g	18000 (25.0% reduction)

Main operator: Jian Wang

Checked by: Zhijun Gong

Inner Mongolia University of Science and Technology
People's Republic of China
June 2019

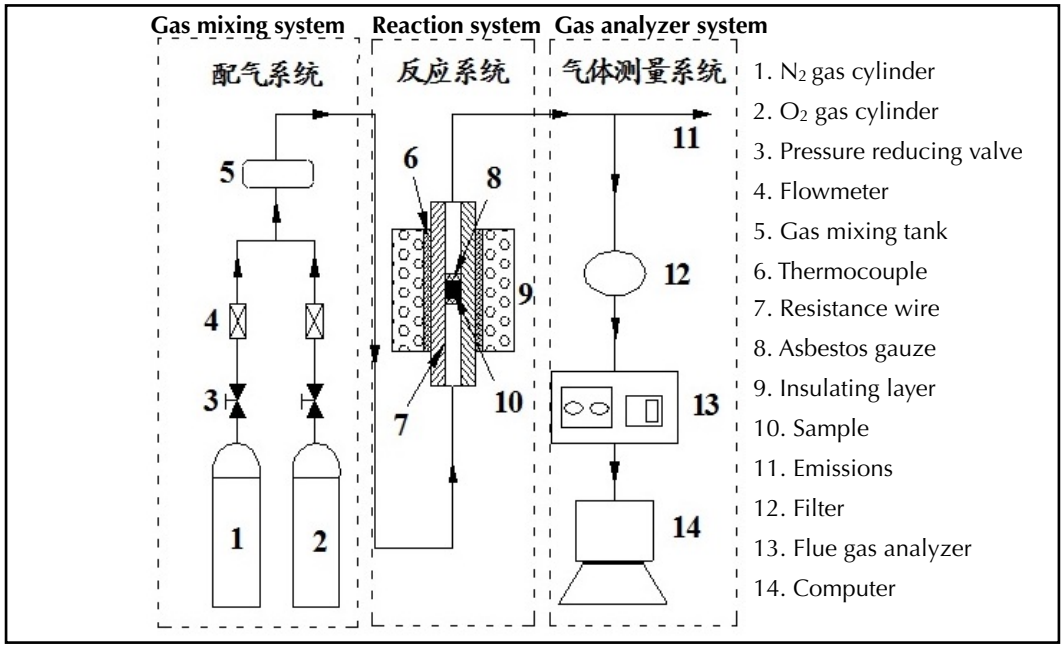
AB Catalyst Simulation Test Report

Purpose of Test:
To evaluate and optimize the operating conditions of catalyst under varied coal catalyst mixtures in various combustion scenarios.

Catalyst activity test procedures:
By controlling the reaction variables to simulate the flue gas respectively, conduct the catalyst combustion reaction under the real flue gas condition, and obtain the performance index of pulverized coal combustion catalyzed by mineral materials (catalyst).

All "catalyst" mentioned in this test report is the AB Catalyst product.

Test equipment:



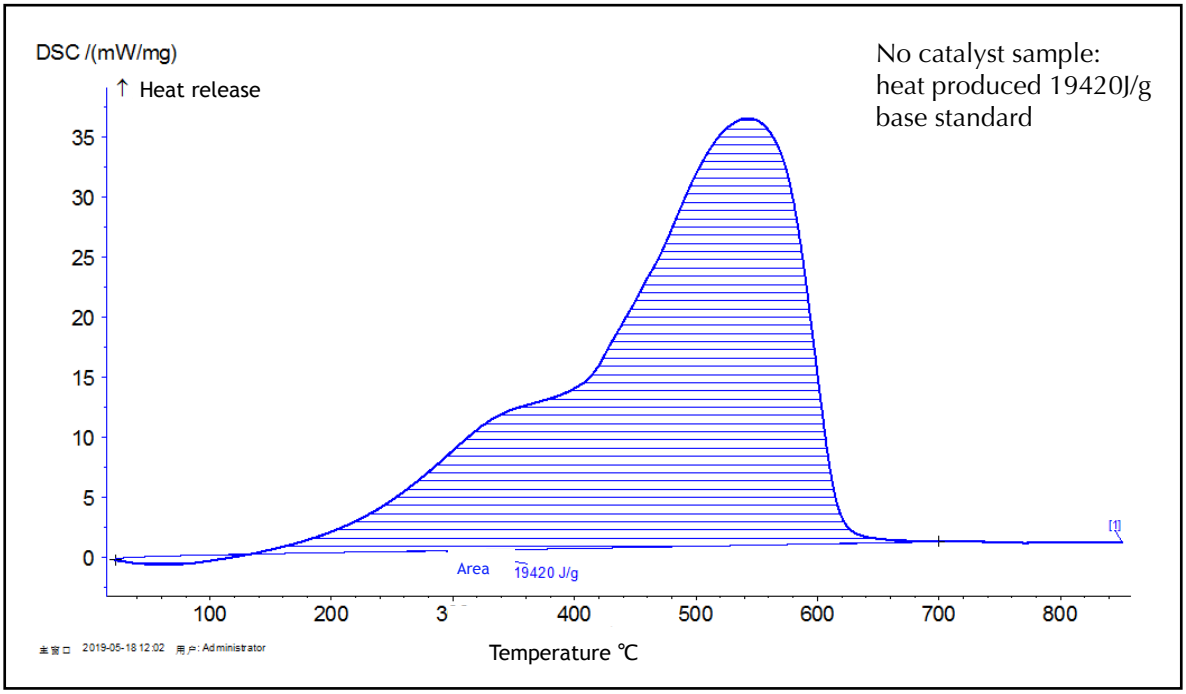
Schematic Diagram of the Reaction Device

I. Catalyst Combustion Efficiency Test

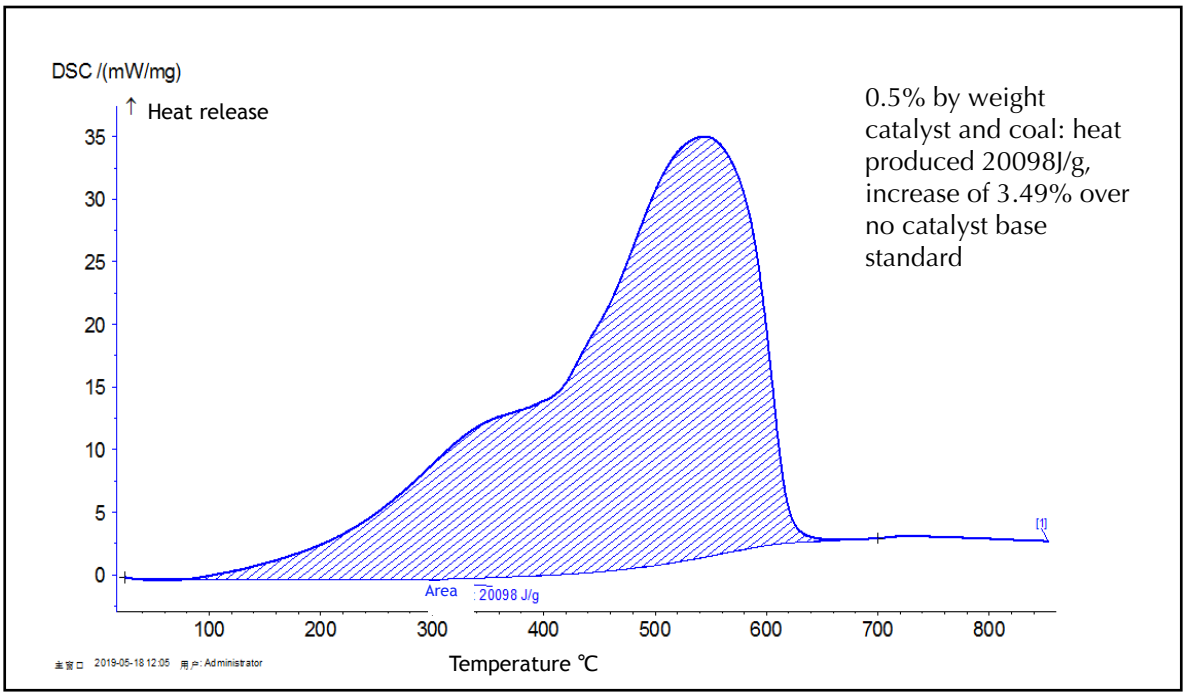
Conduct the heating value test of pulverized coal combustion to calculate the catalyst combustion efficiency under varied catalyst compositions with coal.

Add 0.1g of pulverized coal was combusted, the heating value generated was calculated through differential heat tests establishing the base heating value of the coal only and then varied heating values based on different coal / catalyst compositions. After adding the catalyst, conduct the pulverized coal combustion test with the 3 different coal / catalyst compositions. Conduct 3 groups of tests starting with the proportion of catalyst added at 1%, then according to the test result, change the percentages of catalyst to 0.5% and 1.5% by weight. Calculate the heating value generated by each group of tests, and calculate the value of heating value increased after adding catalyst.

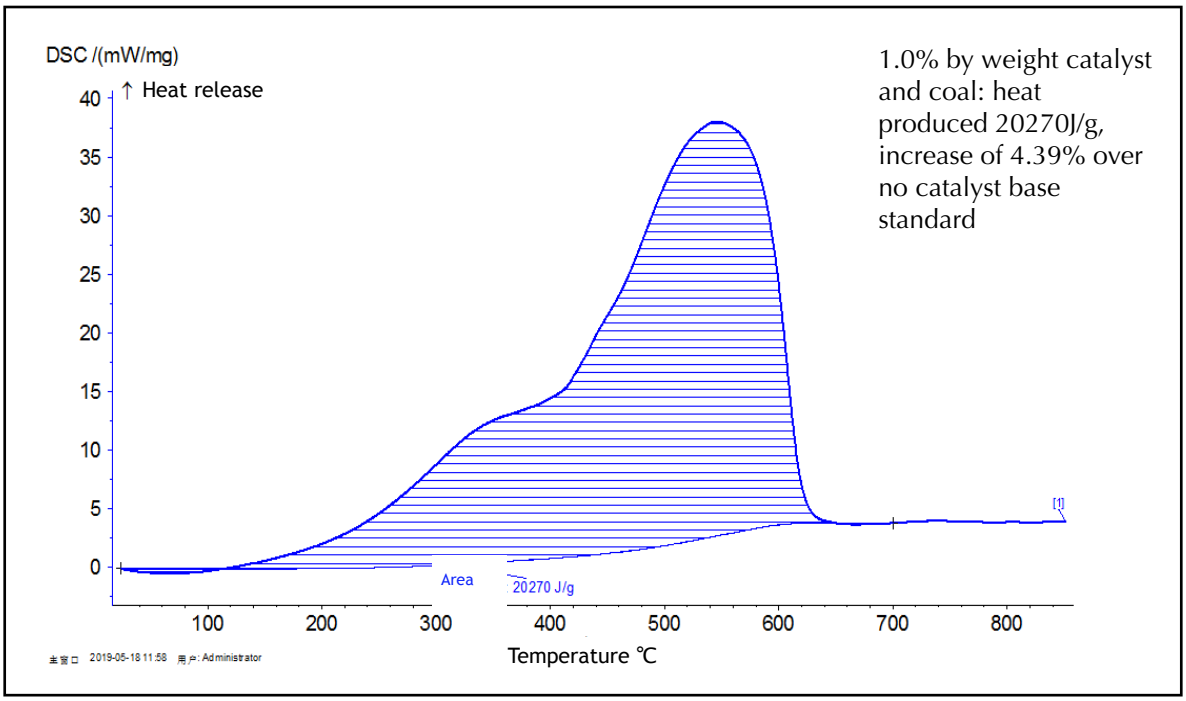
The amount of catalyst in tests (II) and (III) was based on the best performance of the coal / catalyst mixtures according to the results of test (I).



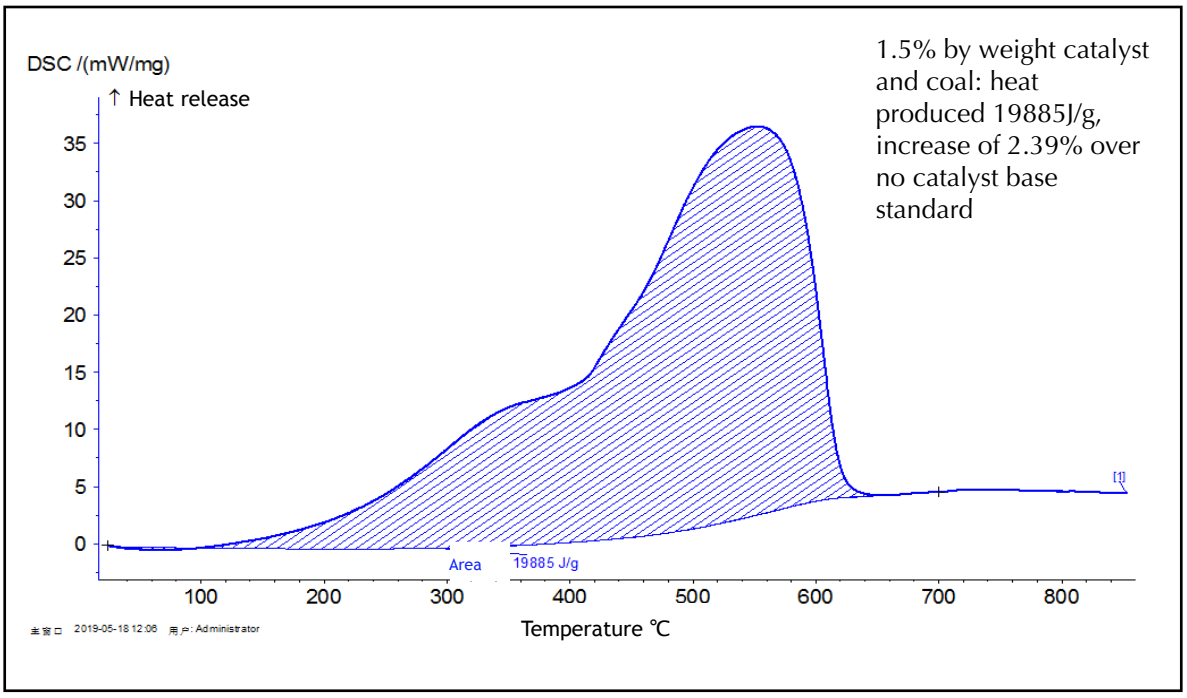
Heat Release Chart - 0% AB Catalyst



Heat Release Chart - 0.5% AB Catalyst



Heat Release Chart - 1.0% AB Catalyst



Heat Release Chart - 1.5% AB Catalyst

Summary of Test Data:

Addition amount of catalyst by weight to the coal sample	0%	0.5%	1.0%	1.5%	Average value
Heating value (J/g) generated by burning sample	19,420	20,098	20,270	19,885	20,084
Adding value (J/g) created by the addition of catalyst		678	850	465	664
Additional percentage (%) of heat generated by the addition of catalyst		3.49	4.37	2.39	3.42

Summary:

1. Adding catalyst increases the heating value of pulverized coal
2. There is an optimal amount of catalyst, and too large amount of catalyst does not increase the heating value.
3. The addition amount cannot be further reduced due to lab conditions.
4. There is no correspondence between the proportion between the lab and the field test, the lab test is only for a qualitative rule.

II. Simulated Flue Gas Test

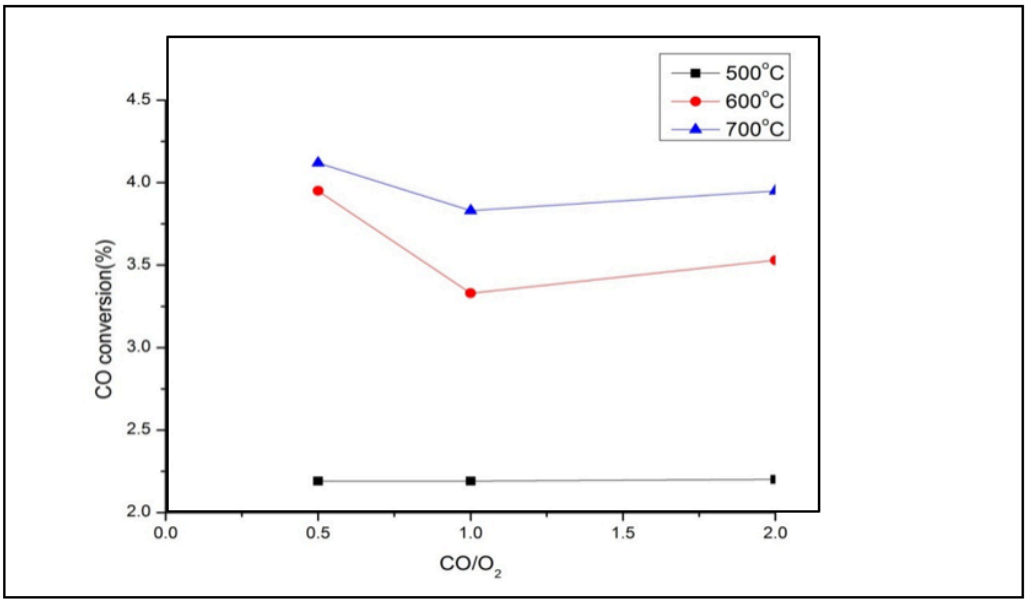
The purpose of the blank group test was to compare samples with zero catalyst with samples that included adding catalyst, and determine whether the added catalyst had catalytic combustion effect.

1. Simulated flue gas blank group test: No catalyst added; introduce simulated flue gas (a certain amount of CO, N_2 was added to provide a balance); then introduce O_2 for combustion, and change O_2 concentration (making CO:O_2 as 1:1, 1:2 and 2:1 respectively); introduce N_2 to be balanced; change reaction temperature (at 500 ℃, 600 ℃, 700 ℃) based on above variables; then conduct 3 groups of tests respectively for a total of 9 tests.

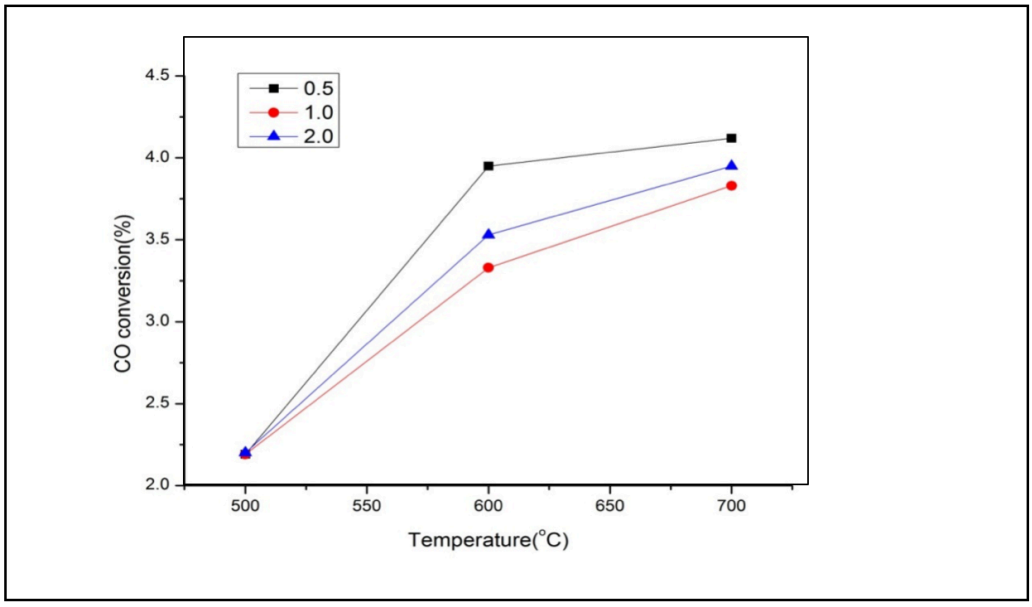
2. Simulated flue gas with catalyst test: 0.1g of catalyst; introduce the simulated flue gas the same as the above test without catalyst (certain amount of CO, N_2 to provide a balance); then introduce O_2 for combustion, change O_2 concentration (making CO:O_2 as 1:1, 1:2, 2:1 respectively); introduce N_2 to be balanced; change reaction temperature (at 500 ℃, 600 ℃, 700 ℃) base on above variables; then conduct 3 groups of tests respectively for a total of 9 groups of tests.

Test Concept: compare the results with the blank group (no catalyst) to see whether adding the catalyst has a combustion effect, and conduct the test to research the influence of temperature and atmosphere on the catalyst CO combustion effect.

Simulated Flue Gas Test - Blank Group Test:



CO Conversion Chart

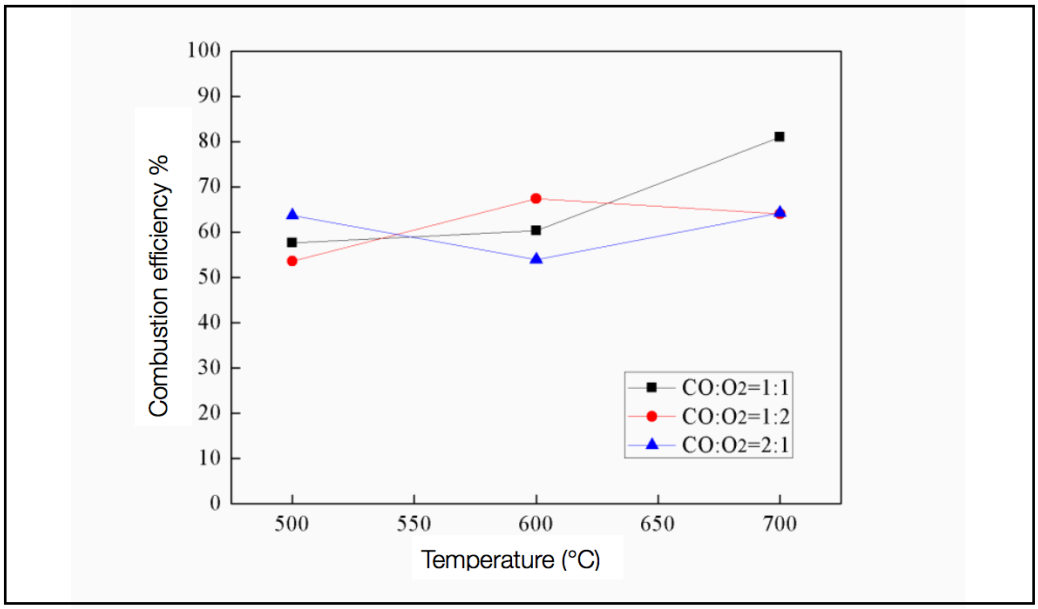


CO Conversion Chart

Summary:

500-700℃, without catalyst, CO oxidation is very difficult (<5%).
Above 800℃, with catalyst, the oxidation of CO is very rapid.

Simulated Flue Gas Test - Catalyst Test



The change of combustion efficiency with temperature after adding AB catalyst

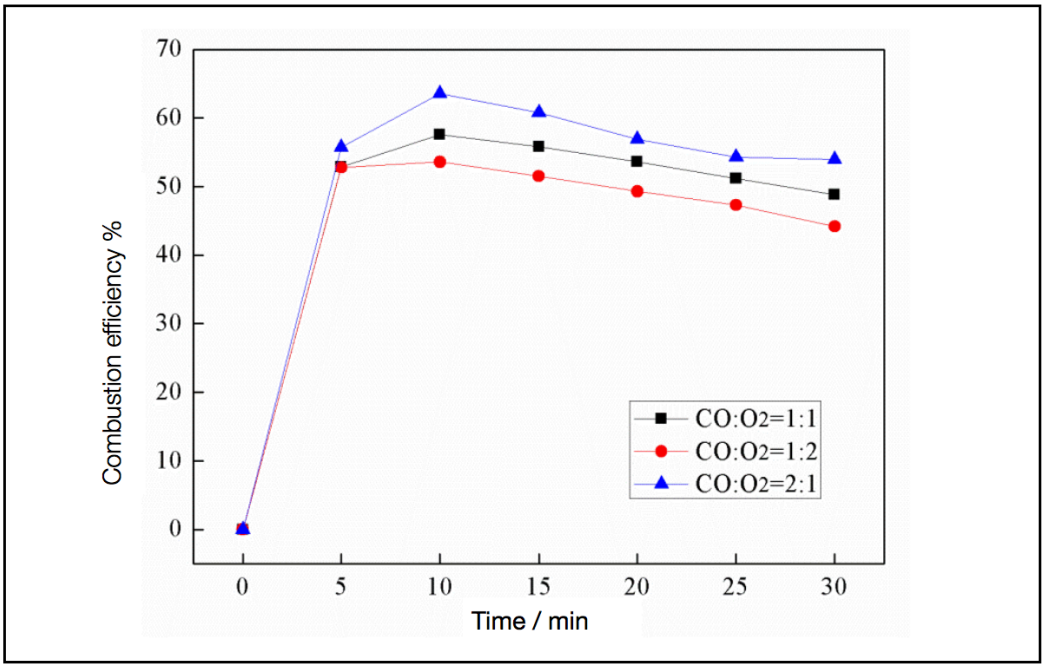


Chart of combustion efficiency changing with time at 500℃

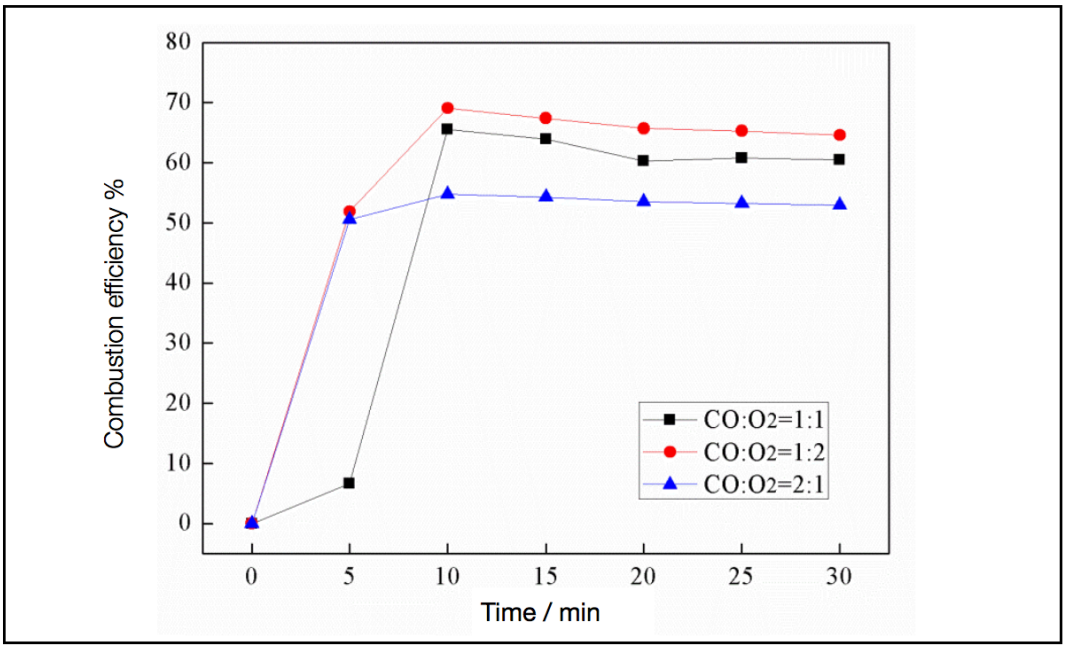


Chart of combustion efficiency changing with time at 600℃

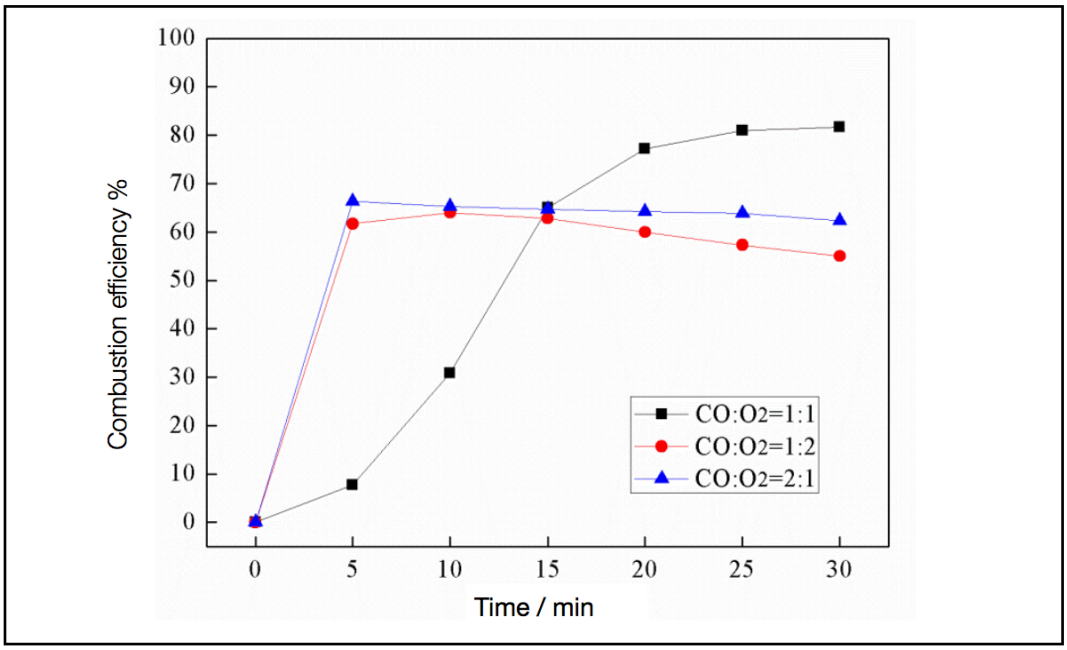
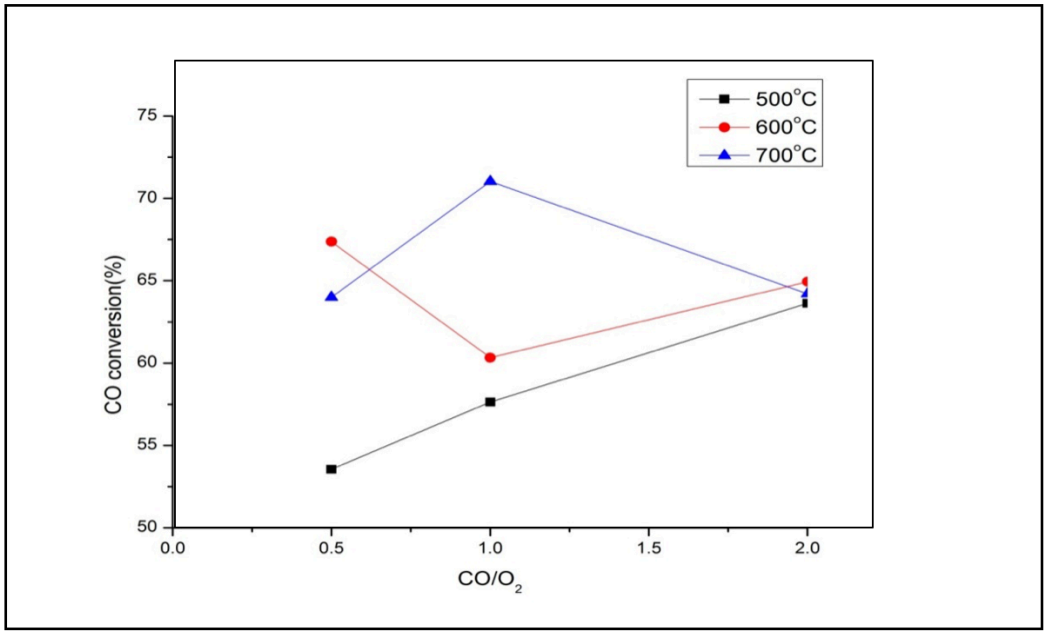
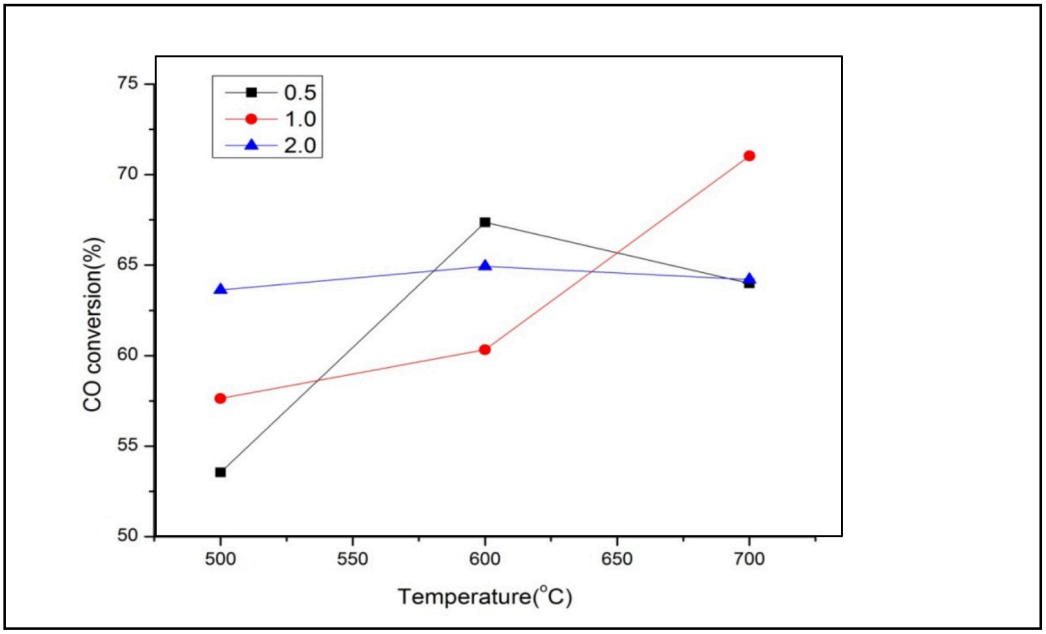


Chart of combustion efficiency changing with time at 700℃



The change of combustion efficiency with CO concentration after adding AB catalyst



The change of combustion efficiency with temperature after adding AB catalyst

Summary of Test Data:

		CO conversion rate percentage	CO conversion rate percentage
$CO:O_2$=1:1	**Catalyst**	AB Catalyst	Blank (No Catalyst)
	500℃	57.63	2.19
	600℃	60.33	3.33
	700℃	71.03	3.83
$CO:O_2$=1:2	**Catalyst**	AB Catalyst	Blank (No Catalyst)
	500℃	53.55	2.19
	600℃	67.37	3.95
	700℃	64.10	4.12
$CO:O_2$=2:1	**Catalyst**	AB Catalyst	Blank (No Catalyst)
	500℃	63.63	2.2
	600℃	63.94	3.53
	700℃	64.21	3.95

Summary:

With catalyst, at a combustion temperature of 500-700℃, CO oxidation effect is very obvious (>50%).

Increasing the temperature is beneficial to catalytic oxidation of catalyst, and increasing CO concentration is also beneficial to catalytic oxidation of catalyst. At low temperature (500℃), the catalyst is suitable for high concentration CO, and the positive effect of the catalyst is obvious.

At high temperature (700℃), catalyst is suitable for low concentration CO, and the positive effect is obvious.

III. Real Flue Gas Test

Purpose of the test: To compare with the blank group, to see whether the catalyst has an effect on pulverized coal combustion, and to research the effect of temperature and atmosphere on catalyst pulverized coal combustion.

This test was performed after test (I) and (II). After completing the simulated flue gas test, and obtaining the optimal condition of catalyst combustion, it was determined that adding 1g of pulverized coal (with 0, 0.2, 0.4, 0.6 grams of catalysts) to combust base on the variables of the simulated flue gas test group to generate real flue gas for the test would provide the best results for test (III).

The method of the real flue gas test is to place catalyst on the top of the coal sample, isolate with silica wool layer between, to more closely simulate the way of injecting catalyst into the centre flame of real boiler, rather than mixing catalyst with coal sample.

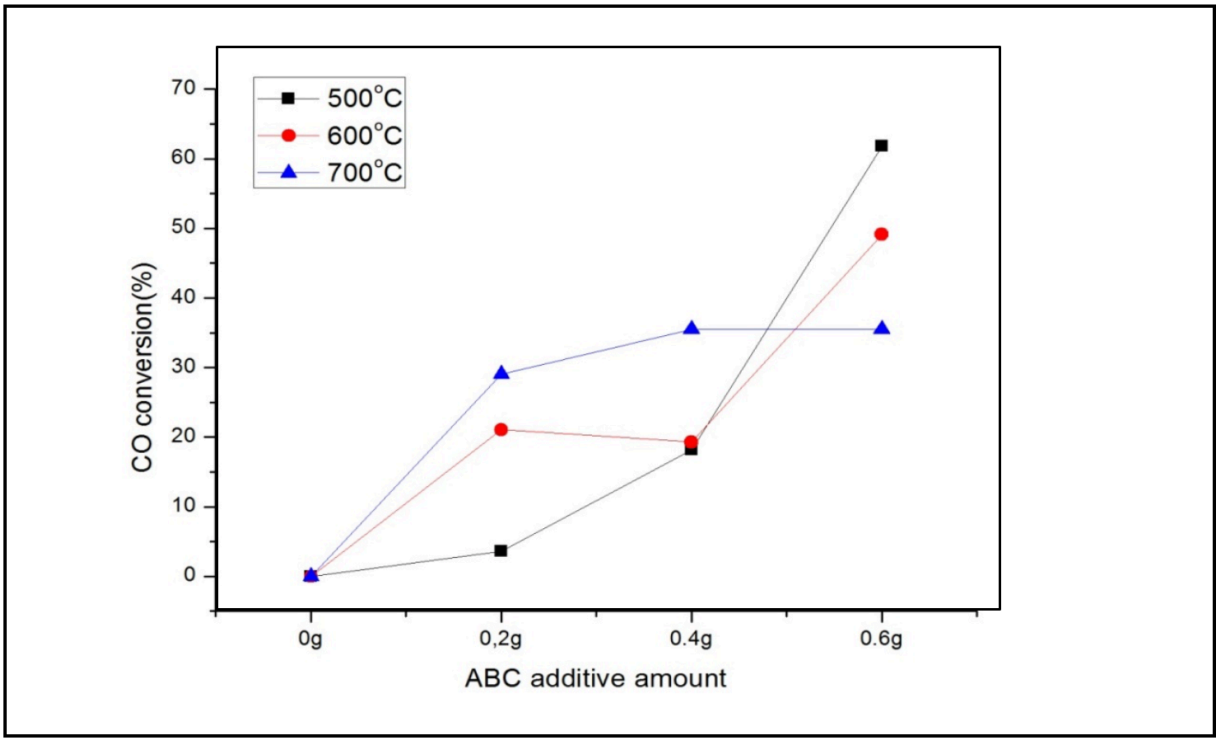
Test (III) Procedure: Add catalyst for the real flue gas: weight 0.1g of catalyst and add to the top of the coal; introduce O_2 to combust the mixture, change the O_2 concentration range (10%, 20%); introduce N_2 to be balanced; change reaction temperature (500℃, 600℃, 700℃) base on the above variables, conduct 3 groups of tests respectively for a total of 9 tests.

Summary of Catalytic Combustion Data:

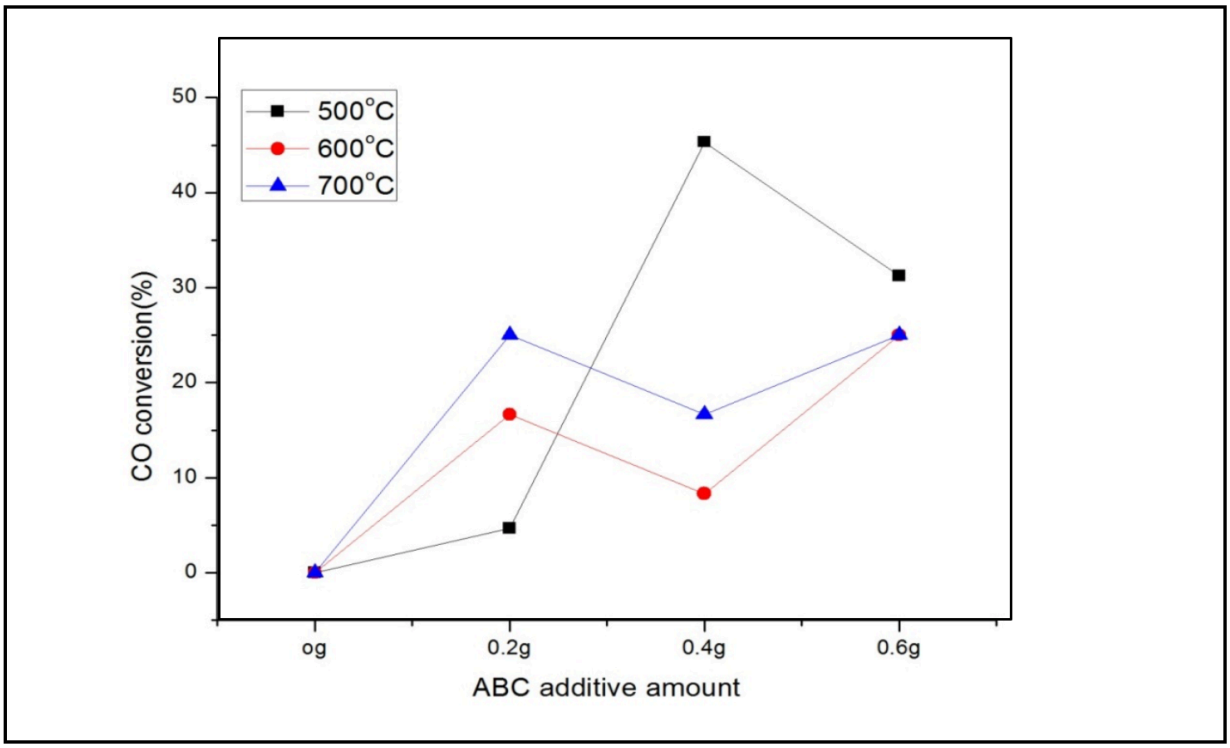
500℃					
10% O_2			**20% O_2**		
Blank group	Stable for 15 minutes	Burn out in 40 minutes	**Blank group**	Stable for 10 minutes	Burn out in 33 minutes
Additive group (1g of coal)	Stable for 8-10 minutes	Burn out in 35 minutes	**Additive group (1g of coal)**	Stable for 6-10 minutes	Burn out in 28 minutes
Stable period	**Catalyst addition amount**	**CO content in flue gas (PPM)**	**Stable period**	**Catalyst addition amount**	**CO content in flue gas (PPM)**
CO（ppm）(stable for 2 minutes)	0g	55000	**CO (ppm) (stable for 2 minutes)**	0g	64000
	0.2g	53000 (3.63% reduction)		0.2g	60000 (4.68% reduction)
	0.4g	45000 (18.18% reduction)		0.4g	35000 (45.31% reduction)
	0.6g	21000 (61.81% reduction)		0.6g	44000 (31.25% reduction)

600℃					
10% O2			**20% O2**		
Blank group	Stable for 6 minutes	Burn out in 30 minutes	**Blank group**	Stable for 5 minutes	Burn out in 25 minutes
Additive group (1g of coal)	Stable for 4-6 minutes	Burn out in 28-30 minutes	**Additive group (1g of coal)**	Stable for 4 minutes	Burn out in 23-25 minutes
Stable period	**Catalyst addition amount**	**CO content in flue gas (ppm)**	**Stable period**	**Catalyst addition amount**	**CO content in flue gas (ppm)**
CO (ppm) (stable for 2 minutes)	0g	57000	**CO (ppm) (stable for 2 minutes)**	0g	42000
	0.2g	45000 (21.05% reduction)		0.2g	35000 (16.67% reduction)
	0.4g	46000 (19.30% reduction)		0.4g	38500 (8.33% reduction)
	0.6g	29000 (49.12% reduction)		0.6g	31500 (25.0% reduction)

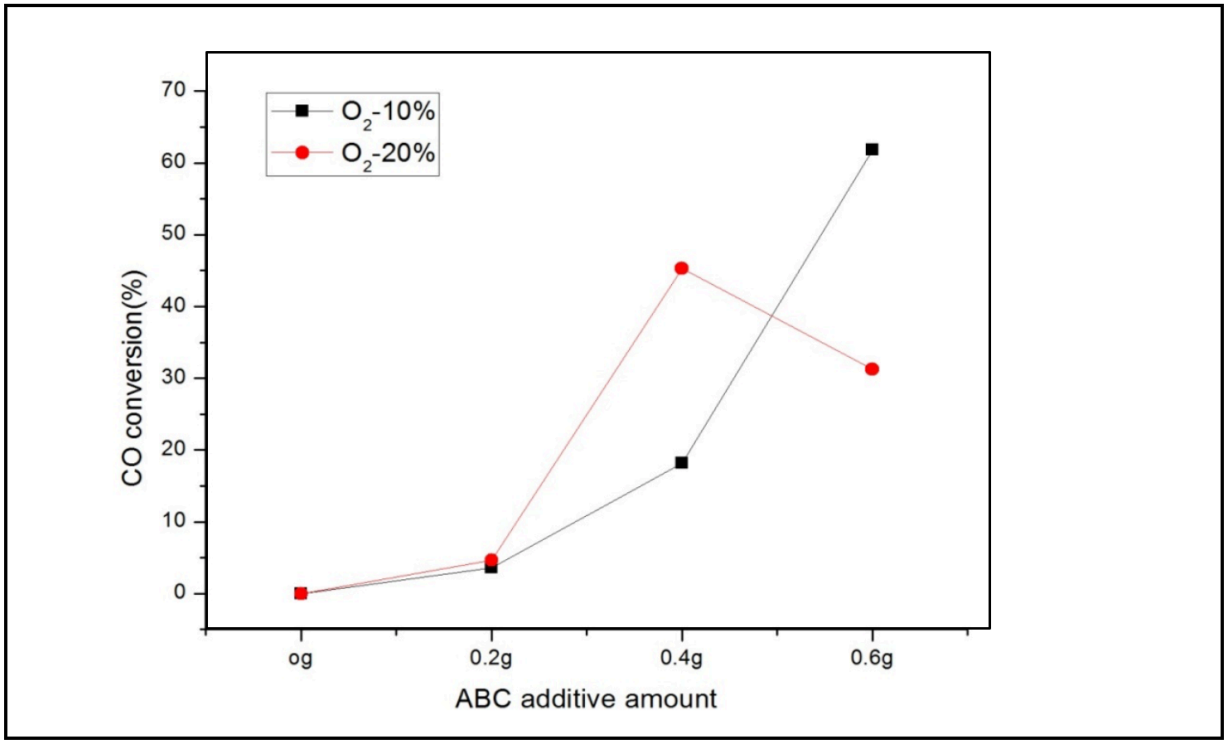
700℃					
10% O_2			**20% O_2**		
Blank group	Stable for 5 minutes	Burn out in 26 minutes	**Blank group**	Stable for 6 minutes	Burn out in 24 minutes
Additive group (1g of coal)	Stable for 3-5 minutes	Burn out in 24-26 minutes	**Additive group (1g of coal)**	3-4分钟稳定 Stable for 3-4 minutes	Burn out in 22-24 minutes
Stable period	**Catalyst addition amount**	**CO content in flue gas (ppm)**	**Stable period**	**Catalyst addition amount**	**CO content in flue gas (ppm)**
CO (ppm) (stable for 2 minutes)	0g	31000	**CO (ppm) (stable for 2 minutes)**	0g	24000
	0.2g	22000 (29.03% reduction)		0.2g	18000 (25.0% reduction)
	0.4g	20000 (35.48% reduction)		0.4g	20000 (16.67% reduction
	0.6g	20000 (35.48% reduction)		0.6g	18000 (25.0% reduction)



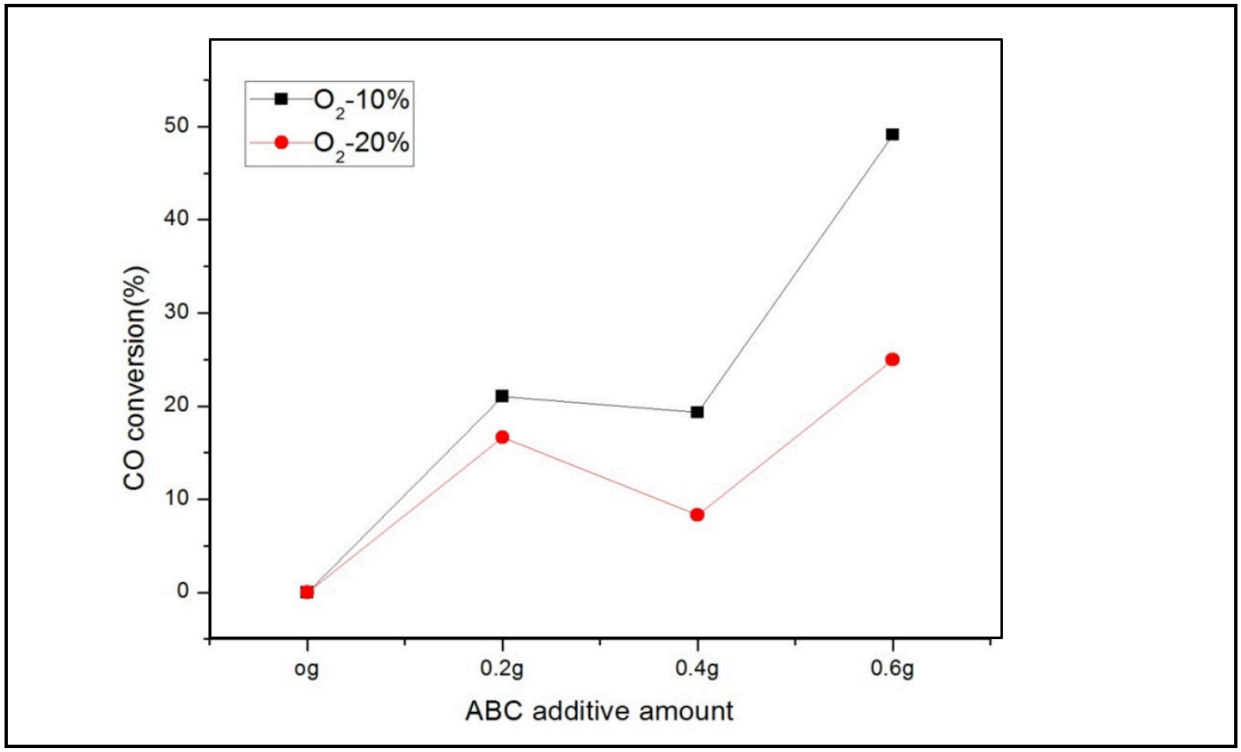
CO Conversion Chart - 10% O_2



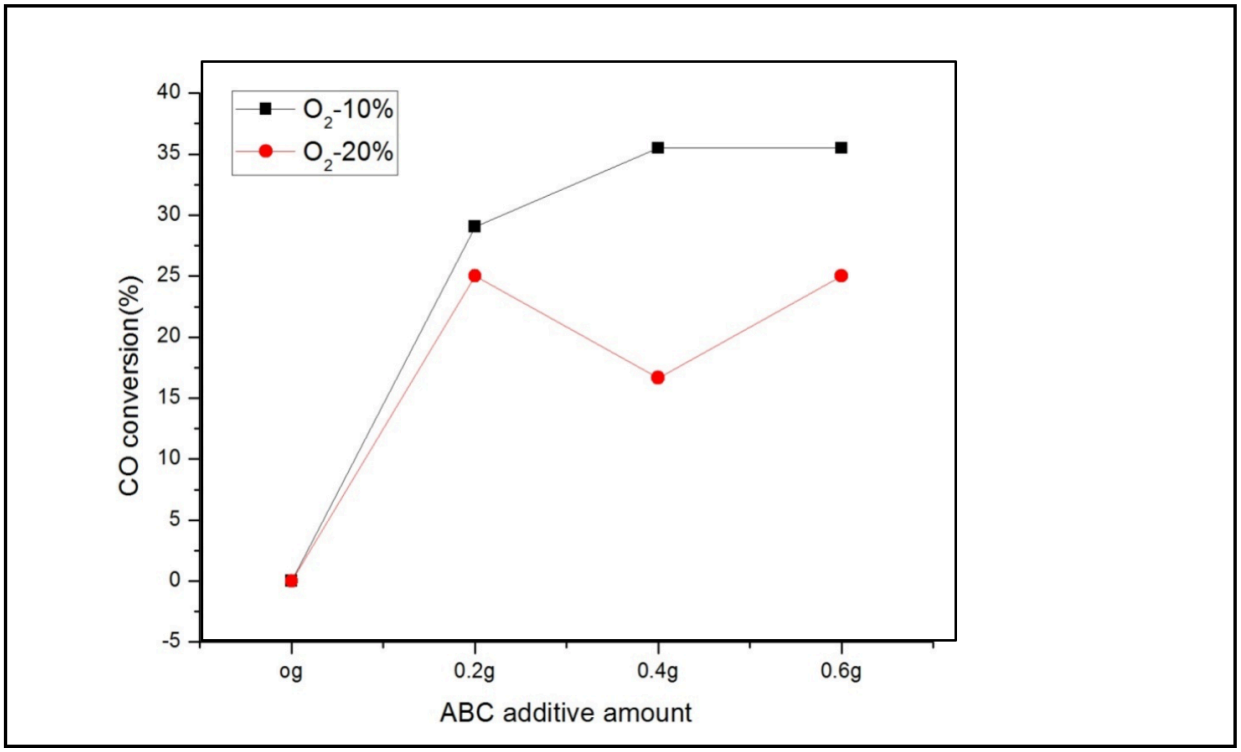
CO Conversion Chart - 20% O_2



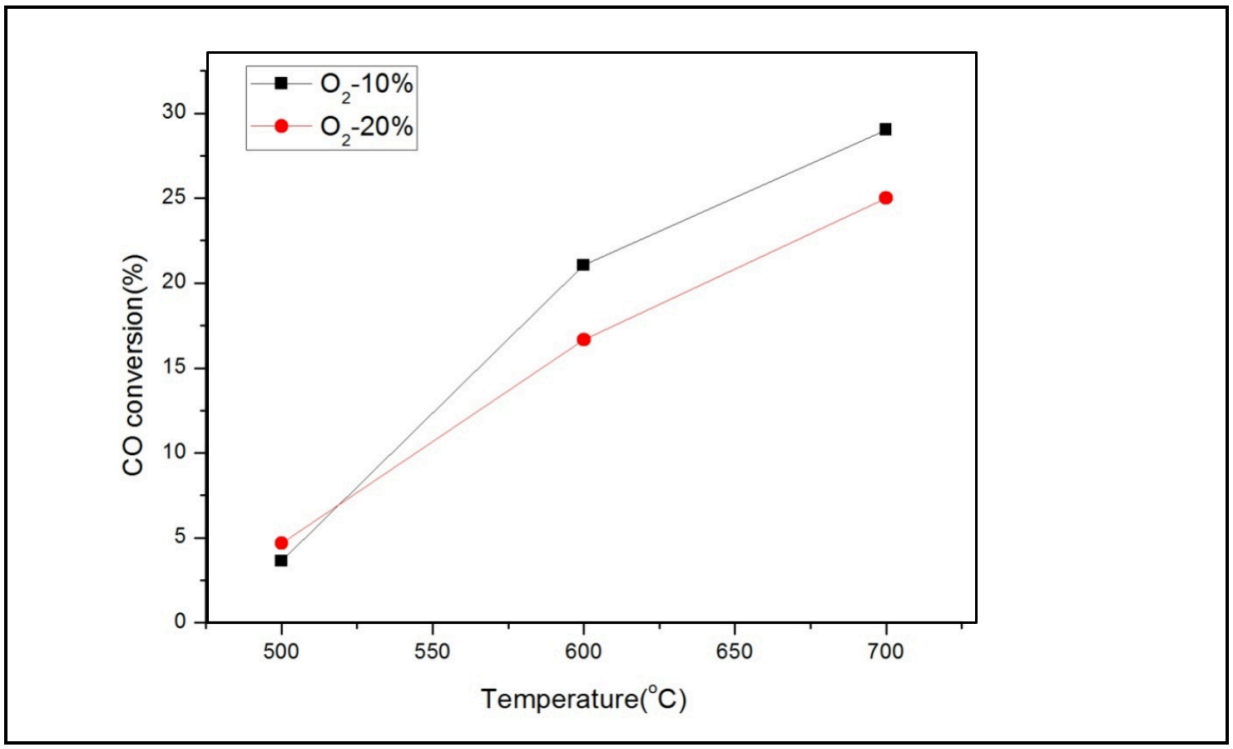
CO Conversion Chart – 500°C



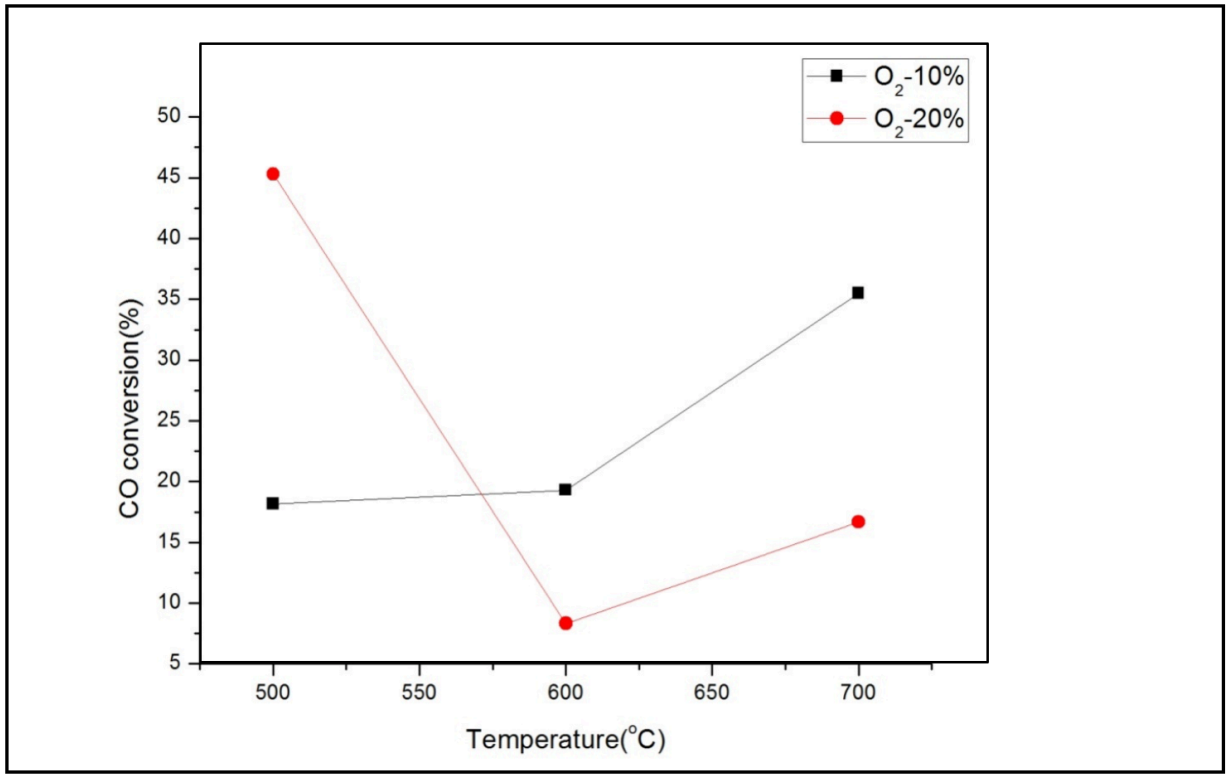
CO Conversion Chart – 600°C



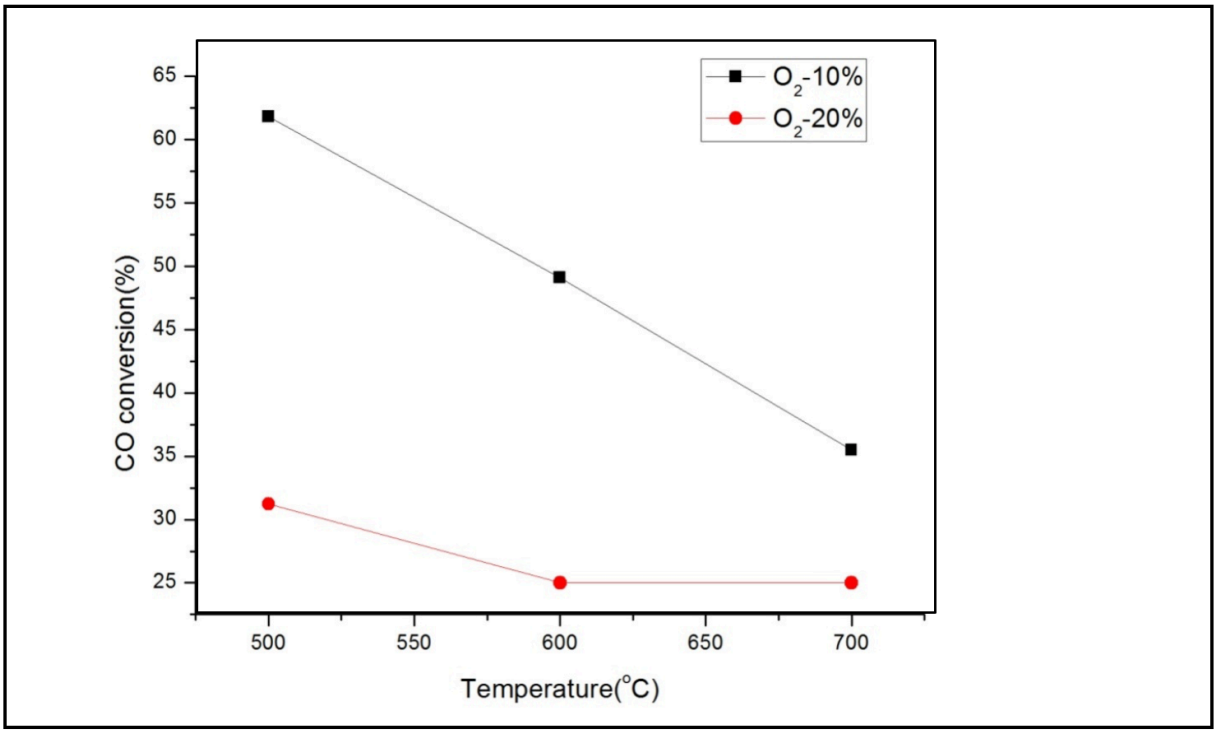
CO Conversion Chart – 700°C



CO Conversion Chart - 0.2g ABC



Conversion Chart - 0.4g ABC



CO Conversion Chart - 0.6g ABC

Summary：

1.With catalyst the oxidation effect of CO is obvious, and the factors affecting the catalytic effect of catalyst include reaction temperature, O_2 content and catalyst addition amount.
2.When the reaction temperature is low (500℃), adding catalyst has obvious catalytic effect; when the reaction temperature is high (700℃), adding catalyst has a more modest catalytic effect.
3.When O_2 content is low in the combustion zone (10%), increasing catalyst addition amount is beneficial to catalytic oxidation of CO. The more of the addition amount, the better the catalytic effect. The effect of catalyst under low oxygen condition is obvious, the best effect can be reached to more than 50% reduction of CO.
4.When O_2 content is normal (20%), there is a suitable value for the amount of catalyst added, while excessive amount of catalyst added is adverse to the catalytic effect. Under the condition of normal oxygen content, the effect of adding catalyst is modest (~30%).
5.The amount of catalyst added has a great impact on the oxidation of CO. When the amount added is relatively small, the higher the reaction temperature, the better the catalytic effect. When the amount added is relatively large, the lower the reaction temperature, the better the catalytic effect.

Overall Conclusions:

The results of comprehensive combustion efficiency test, simulated flue gas test and real flue gas test show good consistency. Specifically, it can be concluded that:

1. The catalytic combustion effect of this catalyst is obvious. No matter the indexes of heating value of pulverized coal, or the conversion rate of CO and the burnout time of pulverized coal, etc., the test results of each group all prove that AB Catalyst has significant catalytic combustion effect of pulverized coal.
2. The temperature window of catalyst is 500℃-700℃, and AB Catalyst has better catalytic combustion effect in this temperature range.
3. When O_2 content is relatively low (<<20%) and CO concentration is relatively high, AB Catalyst has better catalytic combustion effect.
4. The addition amount of catalyst has a great influence on the catalytic combustion effect of pulverized coal, there is a certain relationship among the addition amount of catalyst, reaction temperature and O_2 content. When the temperature is higher the amount of addition is less; and when the temperature is lower, the amount of addition is more. When O_2 content is lower, the amount of addition is more; when O_2 content is higher, the amount of addition is less.